Delta Science Program

Review Panel Summary Report

Draft Plan for Adaptive Management of Fall Outflow for Delta Smelt Protection and Water Supply Reliability.

Review Panel Members:

Denise Reed, *Panel Chair*
Department of Earth and Environmental Sciences
University of New Orleans

Peter Goodwin
Department of Civil Engineering
University of Idaho

Hans W. Paerl
Institute of Marine Sciences
University of North Carolina - Chapel Hill

Ernst B. Peebles
College of Marine Science
University of South Florida

William V. Sobczak
Department of Biology
College of the Holy Cross

Eric B. (Rick) Taylor
Department of Zoology
Beaty Biodiversity Centre
University of British Columbia

Delta Science Program Liaison: Elizabeth Soderstrom

July 1, 2011

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Executive Summary

The US Fish and Wildlife Service (Service) issued a Biological Opinion (BiOp) on the Central Valley Project (CVP)/State Water Project (SWP) operations in 2008 that concluded that aspects of those operations jeopardize the continued existence of delta smelt (DS). The Reasonable and Prudent Alternative (RPA) that was issued with the BiOp calls for implementation of adaptive management of Fall Delta outflow in above-normal and wet years. The Fall outflow action is expected to improve habitat suitability and contribute to higher average DS abundances. The RPA calls for Delta outflow to be managed such that Fall X2 (the location of the 2 ppt isohaline) must average either 74 km or 81 km upstream from the Golden Gate during the month of September and October, respectively, if the water year containing the preceding spring was classified as wet or above normal. 2011 is classified as a wet year invoking the expectation of X2 at 74km. The RPA requires that adaptive management (AM) be used to assess the effectiveness of the action, including a feedback loop allowing the action to be refined in future years from learned information with the objective of improving outcomes. In 2010, the US Bureau of Reclamation (Reclamation) led a planning initiative to develop an adaptive management plan for Fall outflow, but external review suggested that greater benefits to understanding the consequences of the X2 location could be obtained from an active (or experiment-driven) AM approach rather than the passive approach proposed. The AM Plan was revised in 2011 to address these concerns and Reclamation and the Service requested an independent Science Review at the early stages of the plan revision. This Review Panel (Panel) was convened by the Delta Science Program in June 2011 and the present document serves as a review of the Panel's findings and recommendations. The Panel appreciated the opportunity for involvement in the early formative stages of the plan and developed the review in less than 3 weeks to allow recommendations to be fully considered during the final planning for the 2011 Fall outflow. The Panel made 17 primary recommendations, which are summarized below:

1. All parties interested in assessing the effectiveness of proposed actions for DS should engage in the development of the study and monitoring plan for the Fall 2011 action. It will be the largest high flow perturbation to the system in more than a decade and thus provides a rare and potentially unparalleled opportunity to both quantify the benefits to DS and to better understand the linkages between abiotic habitat characteristics, growth rates, survival and fecundity, and interactions with other species.
2. An explicit, succinct discussion of constraints on the provision of controls and replication needs to be incorporated into the Plan including an explanation of why controls and spatial replication within a given study year are not possible. This will ensure the expectations of the adaptive management aspects of the manipulation will be consistent among interested parties. In addition, the long-term AM Plan should include some discussion of statistical

procedures that can be employed to account for interannual variation in variables that might confound the interpretation of changes in DS abundance.

3. The Fall outflow adaptive management should be formulated as a test case for the draft Delta Stewardship Council guidelines on adaptive management.
4. Attention should be focused in the next few weeks on maximizing the scientific knowledge that can be generated during the 2011 Fall outflow, and in predicting how the X2 standard can be achieved for the minimum loss of storage and depletion of coldwater pools in the large reservoirs.
5. The details of the proposed manipulation and monitoring plan should be made available to the public and interested parties to allow others to contribute to monitoring and studies so as to maximize the capability to address DS and other fundamental questions regarding the functioning of the Delta ecosystem. Previous attempts at these types of major manipulations have been scaled back or inadequate monitoring programs were implemented to deduce findings. The opportunity should not be lost this year.
6. The proposed AM Plan should focus on improving the rigor and detail of conceptual models for the DS and other POD-associated species.
7. The revised AM Plan should include descriptions of planned methodologies for estimating vital rates, e.g., growth and fecundity of DS, as response variables.
8. Reclamation should clearly articulate a conceptual model that explains the expected beneficial effect of the Fall outflow manipulation on DS that includes cause-effect relationships rather than biogeophysical correlations. The proposed conceptual model will be the primary driver of the scientific questions to be addressed in the AM Plan.
9. Reclamation, the Service and other agencies should work to support the development and testing of the proposed Life-Cycle Model (Newman et al.). This model will be useful in furthering understanding but is unlikely to be useful for management actions within the next 2-3 years. It is important to continue this initiative, but for 2011 it is necessary to rely on the Conceptual Model approach.
10. The Fall outflow provides an opportunity to assess different approaches of achieving X2 and to test the accuracy of the model for management decisions regarding the placement of Fall X2. The magnitude of variation from normal and low flow years (for which much of the detailed monitoring data is already available) will provide a validation that greatly extends the understanding of the Delta ecosystem.
11. The Panel recommends that efforts are made to standardize the model version, bathymetric grids and boundary forcing used by all parties investigating Fall outflow scenarios with the UNTRIM model (or other hydrodynamic models). This will ensure the discussion focuses on actions and outcomes rather than the specifics of the model setup.
12. The panel strongly urges Reclamation and other agencies to formulate an explicit work plan capable of evaluating changes in the health and condition of DS in response to the X2 manipulation. The current document is deficient

on the details regarding the plan's most important dependent variables. In the absence of reliable abundance data, how will health and condition of the DS population be evaluated? The revised draft must state how health and condition will be evaluated with regard to methodology, sampling design, and coordination of personnel.

13. Parameters that measure the condition of predator and prey species should be targeted by 2011 monitoring and special studies. Those parameters that are found to be useful in explaining DS responses should be assimilated into long-term monitoring.
14. The Plan should incorporate monitoring of response variables in DS that have a clear demographic link to DS both at the individual and population level (otolith inferred growth rates, fecundity, condition factor).
15. Reclamation must show how the proposed monitoring and assessment program will evaluate change from historical data and ongoing monitoring programs.
16. The Fall outflow plan leadership team should include one individual who is given the freedom to ensure that the implementation and monitoring of the plan is her/his top priority and principal responsibility for the next year starting July 1, 2011. The Panel urges leadership at Reclamation and other invested agencies to be responsive to requests for resources, especially time commitments from the agencies most qualified scientists and managers.
17. When finalizing the plan, the authors should incorporate lessons from other large-scale ecosystem restoration or AM plans that have been implemented in other litigious and high-stake environments.

In summary, the panel believes that the proposed experiment/manipulation of X2 in a wet year represents a rare opportunity for a quantum leap in our fundamental understanding of Delta processes. This will help stakeholders develop a common knowledge of key linkages between enhancing outflow, rate of export flows and the benefits to the biological resources and have profound implications to the future management of the Delta.

1. Introduction

.1 Background

The US Fish and Wildlife Service (Service) issued a Biological Opinion (BiOp) on the Central Valley Project (CVP)/State Water Project (SWP) operations in 2008 that concluded that aspects of those operations jeopardize the continued existence of delta smelt (DS) and adversely modify DS critical habitat. The Reasonable and Prudent Alternative (RPA) that was issued with the BiOp calls for implementation of adaptive management of Fall Delta outflow (hereafter "Fall outflow") in certain water-year types. The Fall outflow action is expected to improve habitat suitability and contribute to higher average DS abundances.

The RPA is expressed in terms of X2, the nominal location of the 2 ppt isohaline. The RPA calls for Delta outflow to be managed such that Fall X2 must average either 74 km or 81 km upstream from the Golden Gate during the month of September and October, respectively, if the water year containing the preceding spring was classified as wet or above-normal. There is an additional storage-related requirement to enhance outflow in November that does not have a specific X2 target. The RPA requires that the effectiveness of the action is evaluated by a research and monitoring program, including a feedback loop allowing the action to be refined in future years from learned information with the objective of improving outcomes (i.e., adaptive management). The US Bureau of Reclamation (Reclamation) responded to the BiOp with a "provisional acceptance" letter. In 2009-10, Reclamation and the Service developed and initiated studies designed to increase understanding about Fall X2 and support future management decisions regarding the Fall action. Reclamation has developed a draft adaptive management (AM) plan that aims to facilitate water deliveries while avoiding jeopardy and adverse modification of DS critical habitat. Reclamation also wants a plan that can be carried out in a framework that increases scientific understanding to improve future management actions. There was also a commitment by Reclamation and the Service to defensible and transparent science.

A Review Panel (Panel) was appointed in early June 2011 to review the draft AM Plan and the Charge to the Panel (Appendix I) includes a list of the specific background documents provided for the review. During the Panel's 1.5 day deliberation, additional materials were requested from Reclamation. The planning time-frame for the Fall outflow AM actions is very short, requiring a rapid turn-around of panel reporting. Therefore, no additional materials were considered by the Panel beyond those received by June 17th, 2011. One of the pieces of information requested from Reclamation (additional information on monitoring programs referred to in the Report) was not available by 17th June. The Recommendations of the Panel are based on the information reviewed and discussions with agency staff during the Panel's in-person meeting. It is possible that some of the information called for by the Panel is already available. The Panel has erred on the side of stating what is needed over and above the information that was provided as review materials, rather than be concerned about such redundancy.

The AM Plan draft is still a work-in-progress, but the Panel acknowledges that the Service and Reclamation requested early independent scientific review, when there is still the opportunity to refine elements of the Plan. The following recommendations should be reviewed in the context of the preliminary nature of the draft AM Plan. The feasibility of Plan implementation will depend on how these recommendations are acted upon by Reclamation and their partners. The Panel agrees that it is possible, even at this late date, to implement an effective system manipulation in Fall 2011. The Recommendations included here are offered expeditiously to further that goal, recognizing that there is very limited time to properly plan and execute an effective manipulation.

1.2 Interpretation of 2008 RPA

The 2008 Biological opinion calls for the Service to direct and oversee the implementation of a formal adaptive management plan for the RPA with specific implementation deadlines. Furthermore, an adaptive management plan is described as including a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of actions, a formal process for assessment and action adjustment, and a program of periodic peer review. It was clear during the Panel proceedings that considerable effort has been expended since the Biological Opinion was issued and many of the specific recommendations, e.g., the formation of a Habitat Study Group have been acted on at least in part in the last 2-3 years. In the draft AM Plan, Reclamation asks two fundamental questions (p6, Review of the RPA Action):

1. What kind of Action seems appropriate?
2. What are the most important specific uncertainties that affect management decisions pertaining to Fall outflow?

The ability of the Panel to provide detailed assessment of how Reclamation plans to meet the expectations of the 2008 Biological Opinion is limited by the information provided. For example, it was not clear until the Panel meeting that some of the draft AM Plan is based on the 2010 Habitat Study Group (HSG) and other materials not immediately available to the Panel or referenced in the Plan. A general assessment of the current Reclamation approach relative to the expectations laid out in 2008 can be summarized as follows:

- *description of the details of the proposed action.* There are several ways that the X2 objective could potentially be achieved, but no details of the timing and source of the freshwater flows were provided.
- *clearly stated conceptual model*. This was not provided and although a conceptual diagram is presented in a 2010 HSG document, few details are provided to support the mechanistic linkages included.

- *predictions of outcomes*. The outcomes of the action for the species and how they will be measured, e.g., in terms of growth, have not been articulated.
- *a study design to determine the results of actions*. A study design based mostly on existing monitoring plans was outlined but no details were provided relative to the action to be taken. Furthermore, it is not clear how the study and monitoring designs will gage change against an existing and developing baseline.
- *a formal process for assessment and action adjustment*. The action was not described in any detail, e.g., no mention of the water sources to be used (inflows vs. exports) and no triggers for adjustment were provided.
- *a program of periodic peer review*. No specific plans were laid out.

This review provides more detailed description of these topics and provides recommendations, where possible, aimed to guide the development of an adaptive management plan for the action in accordance with the 2008 Biological Opinion. Figure 1.1 outlines the steps required prior to September 2011 and how these may be influenced in later years by the development of information from new special studies, the key studies initiated in 2010 and the Newman et al. or other simulation models currently under development.

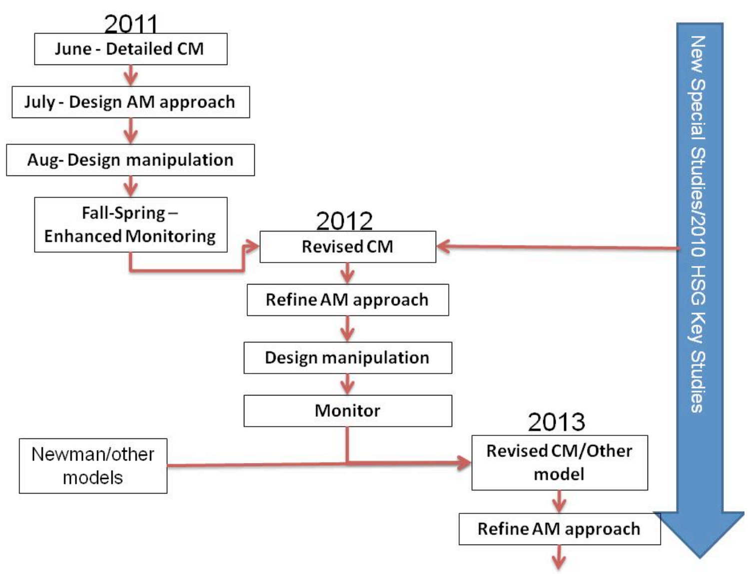

Figure 1.1 Outline of near term needs for exploration of the role of Fall outflow on DS, and how these may evolve over the next 2 years. CM is Conceptual Model, AM is Adaptive Management, and HSG is Habitat Study Group. This iterative cycle should continue beyond 2013.

Figure 11 of the draft Fall outflow management plan, Figure 1.1 and later sections of this report point to the importance of a well-designed X2 manipulation during Fall 2011. The adaptive management approach noted in Figure 1.1 requires, at the very least, articulation of the hypothesized outcome of the manipulation, and how the achievement of that outcome will be measured. As described later in this report, outcomes must be expressed in terms that are more directly relevant to the persistence and recovery of the species (e.g., growth), rather than in surrogate terms such as the provision of habitat or indices of abundance.

1.3 Importance of an Ecosystem Perspective

Habitat condition, food availability and health of the DS under various freshwater discharge regimes are closely linked to and reliant upon ecosystem-level processes. The function and overall condition of the Bay Delta as an ecosystem are of fundamental importance to the persistence of this as well as other native fish species. Ecosystem attributes and processes such as hydrodynamics, salinity, optical and thermal regimes, biogeochemical (nutrients, dissolved gases) and contaminant cycling, and food web dynamics (e.g., Rooney et al. 2006) are all critical elements for evaluating DS habitat condition. Questions of DS health and survival should be examined and quantified in relation to how the ecosystem functions. By assessing DS in the context of broader ecosystem function, more will be learned about the linkage of DS with other ecosystem issues that have either been directly or indirectly linked to DS health (Baxter et al., 2010); including harmful (toxic, hypoxia-generating) cyanobacterial (*Microcystis*) blooms, changes in planktonic community structure and function, pH, dissolved oxygen and contaminant levels, and how the effect of these potential stressors is mediated by salinity, turbidity, and temperature regimes.

The conceptual model used to link various external environmental and endogenous drivers to DS responses should incorporate species-level, community-level *and* ecosystem-scale perspectives. Taking this approach will add value to the overall assessment of impacts of Fall outflow manipulation on DS, since it will also provide useful information on other delta estuarine issues (e.g., pelagic organisms decline (POD), other native fish species, success of invasive species, composition and function of primary and secondary planktonic producers, macrophytes) that are considered to be influenced by current water management practices. One example of an ecosystem level effect related to changing Fall outflow recognized in the BiOp is the potential for significant depletion of the cold water pools in the reservoirs that could impact other species such as salmon in subsequent years. There will be other temperature and water quality effects driven by the flow characteristics in the Delta that need to be anticipated in the Fall outflow management plan.

1.4 Opportunity provided by the 2011 Water Year

Adaptive management is undertaken to learn from actions and to use that learning to improve the likelihood of success of future actions. The availability of water within the SWP/CVP systems this year due to high winter precipitation provides an excellent and rare opportunity to manipulate the system in accordance with the 2008 Biological Opinion. X2 has not been in such a seaward position in the Fall for over a decade. However, the Panel finds that specific planning for fall 2011 is not yet complete, the way in which the system will be manipulated has not yet been determined, and little more than standard monitoring has been considered to support learning. Moving X2 requires the expenditure of considerable resources but 2011 provides a commensurate opportunity for learning. All stake-holders interested in the future of the Bay-Delta environment and the reliability of water deliveries must engage to the maximum extent possible to capitalize on this opportunity which may not recur within the timeframe of the proposed adaptive management plan. The Action will likely be controversial and failure to adequately document the consequences will result in misinterpretation of outcomes and result in the same questions being posed during the next high flow event. Lastly, the Plan needs to contain a clear and convincing explanation of how anticipated driver and response measurements will be assessed against an established baseline. In other words, how will the effects of an above-normal or wet water year be evaluated on the basis of a historic and ongoing monitoring database?

<u>**Recommendation 1**</u>**: All parties interested in assessing the effectiveness of proposed actions for DS should engage in the development of a study and monitoring plan for the Fall 2011 action.** It will be the largest high flow perturbation to the system in more than a decade and, thus, provides a rare, and potentially unparalleled opportunity to both quantify the benefits to DS and to better understand the linkages between abiotic habitat characteristics, growth rates, survival and fecundity, as well as interactions with other species. The unique management and learning opportunity afforded by the high flows in 2011 should be better emphasized in the plan

2. The Framework

2.1 Clarity of structure of the AM Approach

The Department of Interior (DoI) guidance on adaptive management (Williams et al., 2009) includes a number of aspects some of which Reclamation has clearly integrated into the planning process and other elements that do not appear. It is important to recognize that agency-wide guidance has to be interpreted to local situations and that in this case not all components of the DoI approach are achievable. Notable here is the emphasis by DoI on the engagement of agency partners. Williams et al. (2009) note that the involvement of stakeholders from the beginning increases management effectiveness and the likelihood of achieving agreed-upon outcomes. The Panel understands that a Preliminary Workshop for stakeholders was held was held in May 2011, but it is unclear how input was incorporated into the Draft AM Plan or what the future stakeholder engagement will be for Fall 2011. Given the magnitude of resources to be devoted to the Action, this probably hinders broad acceptance of the plan and further exacerbates the mistrust that often characterizes attempts to balance efficient use of water resources with species recovery goals. It is possible that the plan was scheduled for release following Panel review. However, the release of any plan to stakeholders so close to implementation fails to fulfill the need for stakeholder engagement described in the DoI manual.

Furthermore and as described in more detail below, the plan fails to articulate explicit and measurable objectives – an essential element of any adaptive management plan. The DoI technical guide (Williams et al., 2009) calls for both set-up and iterative phases and the plan does conform to this format. However, the details of each, especially foundational aspects such as modeling are poorly presented. According to the DoI technical guide '*A formal approach to adaptive management uses the tools of structured decision analysis to inform and analyze the problem. A key step is to predict the effects of management actions that are relevant to the objectives. But predictions require models, whether conceptual or quantitative*' (Williams et al., 2009, page 12). Currently, the proposed mechanistic and Bayesian models appear more like overly complex appendages than integrated components of the AM approach. It is incumbent that a well-grounded conceptual model be developed as soon as possible as a guide for testing hypotheses, formulating the basis for evaluating change with respect to the relationship of drivers and responses, and justifying the work plan. The lack of clear use of detailed conceptual models to link actions to objectives is probably the greatest weakness of the plan provided to the Panel.

It is also important to note that the Fall outflow manipulation does not lend itself to the 'classic' active adaptive management approach. There is no opportunity for a control (there is only one X2 to manipulate at any given time) and any attempt at experimentation within a year by altering operational regimes (e.g., changing the position of X2 or the sources of water) during the September to October period would be confounded by changing externalities and/or the progressive life stage of DS. The Panel does not consider the lack of a true active adaptive management experiment as especially problematic. It means that expectations of the adaptive management approach must be modified – true experiments are simply not possible when the system cannot be replicated. However, well-planned and studied system manipulations can still result in both increased knowledge and a potential benefit to the species. Potential AM approaches for the Delta have been the subject of much discussion (e.g., Independent Science Advisors, 2009, the recently released draft of the Delta Plan). This manipulation provides an opportunity to demonstrate how such approaches can be used on a large scale in the Delta to inform central issues.

2.2 The Clarity of the Proposed Action

Reclamation has not explicitly defined the experimental manipulation in regards to water sources and pumping strategies that will result in desired movement of X2 and increase of DS habitat. This is a critical omission in the current draft report that requires immediate action. Forecasting and predicting the outcomes of the manipulation are contingent on this hydrological description of the experimental manipulation. Failure to describe the exact hydrological manipulation well in advance of the experiment potentially jeopardizes the success of the project.

The central issues that must be dealt with are the balance of increased inflow vs. decreased exports and how that will influence the proportions of Sacramento

River and San Joaquin River water in the area of DS habitat. Positioning of planktonic organisms, turbidity, and temperature are likely influenced by decisions regarding the water balance and weight of Sacramento River input. In addition, the energetic base of the food web is influenced (in potentially negative and positive ways) by the relative contribution of the San Joaquin River into the manipulation. The Panel recommends that the X2 manipulation must be explained in regards to an explicit hydrological budget prior to the start of the Fall outflow manipulation. This will allow a solid study design, predictions of the expected 2011 conditions and outcomes that both conserve coldwater pools and maximize the learning from the 2011 Fall outflow management to occur. Determining the water budget is a first-order, high-priority activity that must be formulated immediately. Failure to take immediate action on this task potentially undermines both the execution and scientific value of the proposed manipulation.

2.3 The Fall outflow Manipulation

2011 provides an unusual opportunity for a quantum leap in our understanding of the link between DS and Fall outflow. The stark reality of the situation is that such a high water year may not occur again for several years, and water availability will become an increasing source of conflict. It is essential that all agencies and interested parties involved in this ambitious and rare ecosystem-level manipulation be fully aware at all levels of the magnitude of the 2011 opportunity. Institutional failure to seize this ecological-hydrological moment in time may handicap future efforts at large-scale ecosystem restoration and experimentation. The Panel concludes that the immediate mobilization of financial and human resources is necessary at all staffing levels in multiple agencies to ensure proper implementation of the experiment.

The basis of the Plan framework is the manipulation of freshwater flow levels into the Delta (i.e., the treatment) coupled with subsequent monitoring of various abiotic and biotic variables that will be affected by this manipulation (i.e., the response variables). The predicted responses stem from the conceptual model linking flow to abiotic changes and then to biotic responses of DS (and their prey and predators). Unfortunately, the complexity of the physical structure of the Delta does not lend itself to the provision of a proper experimental control (i.e., an area that will not be affected by flow changes that can also be monitored). It is also very difficult to conduct spatial replication of treatments and controls. Although temporal replication (i.e., across years) might be possible, the uncertainty of when “wet years” may occur to allow replication of treatments, and the presence of confounding interannual variation on treatment effects make this form of replication problematic. In this regard, it must be made clear how the proposed monitoring and assessment program will evaluate change against a backdrop of existing and ongoing monitoring data. This is essential for quantifying the relationships between hydrologic forcing and biotic responses in the context of historic and future water discharge scenarios for the Delta. In summary, the major biotic response variable of interest is inadequately described in the Plan and presumably ultimately relates to increased abundance of DS or some correlate of DS biology with a clear conceptual link to abundance (e.g., growth, fecundity). These are *critical* aspects of the plan given the (normally) essential need for replicated controls in adaptive management experiments and in justifying expensive manipulations to managers and the public in general (Walters 2007).

Recommendation 2: **An explicit, succinct discussion of constraints on the provision of controls and replication needs to be incorporated into the Plan including an explanation of why controls and spatial replication within years are not possible.** This inclusion will ensure expectations of the adaptive management aspects of the manipulation are consistent among interested parties. In addition, the long-term adaptive management Plan should include some discussion of statistical procedures that can be employed to account for interannual variation in variables (e.g. differences in water temperature) that might confound the interpretation of changes in DS abundance or correlates of DS abundance (e.g., growth rate – see below) in response to changes in flow across temporally spaced replicates (e.g., 2011 versus 2014, etc).

Recommendation 3: **The Fall outflow AM should be formulated to provide a test case for the draft Delta Stewardship Council guidelines on adaptive management. As noted, conditions in the Delta rarely allow for true experimentation.** The AM approaches adopted here could result in an improved process for other applications of AM in the Delta.

Recommendation 4: **Attention should be focused in the next few weeks on maximizing the scientific knowledge that can be generated, and in predicting how the X2 standard can be achieved for the minimum loss of storage and depletion of coldwater pools in the large reservoirs.** As already stated, Reclamation and other interested parties should exploit the 2011 high flow adaptive management opportunity to the maximum extent possible, but it should be recognized that significant modifications to the plan for future years are likely to be made based on the findings of this high flow year. Implementation of a detailed design and logistical planning of an AM project on this scale would ideally have at least one year of preparation but the Panel thinks that significant advantage of this opportunity can still be taken. The limited time should be invested in the design of the Action, monitoring and analysis for 2011, rather than developing the perfect multi-year AM plan.

Recommendation 5: **The details of the proposed manipulation and monitoring plan should be made available to the public and interested parties to allow others to contribute to monitoring and studies so as to maximize the capability to address DS and other fundamental questions regarding the functioning of the Delta Ecosystem.** The Panel hopes that the research community, water users and NGOs may conduct supplemental monitoring to further our understanding of the ecosystem services provided by the Fall outflow manipulation. This has also been expressed as moving toward a 'single version of the truth' where the best-available science with a quantification of the inherent uncertainties is developed and separated from the difficult policy decisions that must be made (Nunes, 2011). The Panel expects that the 2011 manipulation will be significant enough to address some of the fundamental questions posed by Reclamation in the Draft AM Plan and presents an opportunity to invest in monitoring to draw defensible scientific conclusions. Whatever Fall action is adopted, the decision is likely to be criticized and contested. Previous attempts at these major manipulations have been scaled back or inadequate monitoring programs were implemented to deduce findings. This opportunity should not be lost.

3. Modeling

3.1 Conceptual Model

Numerical modeling, such as the Bayesian approach outlined in the draft AM Plan, has the potential to unite species-specific, seasonal conceptual models (e.g., Fall outflow relationships with DS) within the complete life cycle perspective and ultimately within a larger ecosystem context, enabling the development of well-supported and defendable predictive capabilities. However, in a discussion with the Panel, Dr. Ken Newman (Service) indicated his numerical modeling would be based on time-series data that span decades, and therefore data generated during the first years of the implementation of the AM Plan would have little influence on the model's performance. It is the opinion of the Panel that development of numerical models, while important, is beyond the scope of the proposed AM Plan (in the context of the Fall 2011 X2 manipulation) and should be regarded as a parallel effort that will benefit from improved rigor and detail in the species-specific conceptual models.

Conceptual models for individual POD-associated species should undergo continual development and evaluation until reasonable assurance can be attained regarding the stability of the models' representational rigor. Because this rigor should persist throughout the range of expected environmental variations, the opportunity to collect data under high-outflow conditions during Fall 2011 is particularly important.

Where possible, processes and linkages within conceptual models should be "disaggregated" to allow identification of the most promixal factors that work in concert to drive target response variables (e.g., species abundance or species health and condition). Once identified, driving factors can be represented by parameters that can be readily measured, and these parameters can be incorporated into either special studies or longer-term monitoring. Data for such parameters will likely be highly useful in the numerical models that are being developed in parallel to conceptual models.

The conceptual model for DS, as represented by Figure 11 of the draft AM Plan, identifies a linkage between Fall outflows and improved vital rates (improved survival and growth, resulting in improved spawning-stock biomass), which is equated with improvements in fecundity and subsequent recruitment. The conceptual model should be amplified to acknowledge that 1) size-specific fecundity may vary as a function of batch size and inter-spawning interval, 2) stock-recruitment relationships are largely unpredictable, and 3) the presently reduced state of the DS stock may make it more likely to exhibit compensatory density dependence. As stated above, the processes that affect vital rates need to be disaggregated and the parameters that best represent component processes need to be formally identified. The revised plan should include descriptions of planned methodologies for estimating vital rates as response variables.

3.2 Life Cycle Model (Newman et al.)

DS are elusive and difficult to study due to their small size, behavioral characteristics, short life cycle and the complex nature of the Delta. The POD and other studies have provided a solid foundation for a life-cycle model, and a series of ongoing studies has been implemented to address gaps in knowledge. A life-cycle model is being developed by Dr. Ken Newman (Service) and colleagues, although the work is still in its formative stages. The Newman model team effort is very strong scientifically and includes hydrodynamic modelers, ecologists and fish biologists with extensive experience in the Delta. The first task will be to synthesize available knowledge and to mine the extensive datasets that have been collected on DS. A model will then be developed on the basis of this available information and supplemental studies and monitoring will be initiated to fill the critical knowledge gaps.

It is expected that the AM Plan will 1) build on this synthesis of knowledge, 2) continue to address process-oriented knowledge gaps, 3) actively evaluate the validity of all linkages, 4) adaptively revise the conceptual model as new information is obtained, 5) coordinate with other Delta researchers, including the Newman team, in an attempt to reach reasonable consensus on the most accurate representation of the conceptual model, and 6) interact with the Newman team to guarantee that the conceptual model has maximum utility to the numerical, life-cycle modeling effort.

The concept of fully utilizing past data, archived samples, and new technologies (such as otolith studies) is also a very logical and prudent step. As an explicit attribute of an AM Plan, both life-cycle models and conceptual models can serve to identify knowledge gaps and help prioritize future research and monitoring programs. However, the Newman life-cycle model is unlikely to provide any guidance in management decisions for at least 2-3 years. This type of numerical modeling should definitely be a core component of the AM Plan in the future, but it cannot be relied upon as guidance for the 2011 Fall outflow action.

3.3 Integration with other modeling initiatives

Simulating the hydrodynamic flow structure, salinity, water temperature, turbidity and water quality, and the transport and fate of particles (including species that rely on '*tidal surfing*') is an immense challenge. However, in the past decade the modeling community has made great strides through organizations such as the California Water and Environmental Modeling Forum (CWEMF) that has allowed a constructive dialogue and objective comparison between modeling approaches. Therefore much is now known about the advantages and disadvantages of the various modeling approaches, the uncertainties associated with the hydrodynamic models and a general consensus on where the greatest sensitivities and gaps-in-knowledge exist.

Reclamation intends to use UNTRIM as the basic hydrodynamic model for simulating flows and particle tracking. UNTRIM is also being linked to a sediment transport model SEDIMORPH, although it is unclear whether the sediment transport and turbidity component will be operational in time for decisions related to study of the 2011 Fall outflow effects. Since UNTRIM is already being used for several concurrent studies, it is well understood and there is a cadre of experienced users. Enhanced monitoring in Fall 2011 will provide an opportunity to quantify the predictive capability of the model for future management actions and perhaps refine the model detail in areas where good agreement between observations and predictions are currently elusive. It is not clear which version of the model grid and calibration of the model will be used, or if the model, boundary forcing, bathymetric grid and calibration files will be open and available to other parties.

UNTRIM has probably been used to simulate X2 locations for different outflow scenarios. It is important for the AM Team to have direct access to the modeling team and to communicate findings. If there are multiple groups modeling the Fall outflow X2 scenarios, the Panel recommends that the same versions of model, bathymetry and boundary forcing – at least within federal and state agencies – are used, to avoid perceptions of 'dueling modelers'.

There is uncertainty about the source and persistence of turbidity in the Delta, for example: what proportion is organic compared with inorganic material, what are the causes of seasonal variability, how important are processes such as flocculation and resuspension? Despite the insightful papers by Kimmerer (2004), Schoellhamer (2011) and the current study by Wright and Schoellhamer, it is unclear if the organic contribution to turbidity, both in terms of organic particles and the role of organic substances in fine particle aggregation and settling, is being adequately addressed. The high flows of 2011 present a rare opportunity to supplement current studies and to increase understanding over a broader range of flow conditions – thus rigorously testing current model algorithms and conceptions about important processes.

<u>Recommendation 6:</u> The proposed adaptive management plan should focus on improving the rigor and detail of conceptual models for the DS and other POD-

associated species. Development of numerical models is beyond the present scope and should be regarded as a parallel effort that will be supported by improved conceptual models.

Recommendation 7: The revised plan should include descriptions of planned methodologies for estimating vital rates, e.g., growth and fecundity of DS, as response variables.

Recommendation 8: Reclamation should clearly articulate a conceptual model for that explains the expected beneficial effect of the 2011 Fall outflow manipulation on DS that includes cause-effect relationships rather than biogeophysical correlations alone. The proposed conceptual model will be the primary driver of the scientific questions to be addressed in the adaptive management plan. It was clear to the Panel that the Delta Scientific Community has been formulating a conceptual model since 2007 but only a simple version is described in the Report. Despite the uncertainties surrounding the life cycle of DS, it is important to work from a more detailed description, even if some of the linkages are presented as testable hypotheses. This will help focus the monitoring effort in 2011 and put it in context with regard to historic and ongoing (i.e. prior to the manipulation) monitoring efforts in order to best gage “change” in the system in response to this above-normal water year.

Recommendation 9: Reclamation and other agencies work to support the development and testing of the proposed Life-Cycle Model (Newman et al.). This model will be useful in furthering understanding but is unlikely to be useful for management actions within the next 2-3 years. It is very important to continue this initiative, but for 2011 it is necessary to rely on the Conceptual Model approach.

Recommendation 10: The Fall outflow provides an opportunity to assess different approaches of achieving X2 and to test the accuracy of the model for management decisions regarding the placement of Fall X2. The magnitude of variation from normal and low flow years (for which much of the detailed monitoring data is already available) will provide a validation that greatly extends the range of flow conditions. It also will allow further insights to turbidity patterns at high fall releases and extend relationships between suspended sediment and turbidity.

Recommendation 11: The Panel recommends that efforts are made to standardize the model version, bathymetric grids and boundary forcing used by all parties investigating Fall outflow scenarios with the UNTRIM model. This will ensure the discussion focuses on actions and outcomes rather than modeling specifics.

4. Monitoring

4.1 General Comment on Health and Condition

The ecosystem-level manipulation of the Delta's Fall X2 location should be founded on a scientifically sound conceptual model that predicts outflow effects on such factors as the amount and quality of DS habitat and improvements in DS abundance and condition. Characterizing the abiotic habitat is a central aspect of the experiment and this can be based on parameters such as salinity, turbidity, and temperature. Biogeochemical and biotic properties that further influence DS should also be examined, with an emphasis on DS health and condition. Quantifying change in the abundance of DS is challenging due to the population's low numbers, variability among abundance estimates, and the possibility that excessive sampling may be detrimental to the population; hence, measuring health and condition data are critical to the project's overall success. The draft AM Plan had little detail regarding evaluation of DS health and condition, but follow-up text provided by Reclamation included such material, leading the Panel to understand that Reclamation and others are planning a concerted effort to examine DS growth, fecundity, and eco-toxicology. We encourage such efforts and stress that these are fundamental dependent variables that must be articulated in detail in order to ensure the overall success of the project. Specific metrics of heath and condition that should be monitored are described below (see sections **4.3 and 4.4** below).

4.2 Water Quality

Water quality (WQ) plays a central role in the eco-physiological condition, fecundity, and survivability of the DS as well as other native fish species that use the Delta as a nursery and foraging habitat. WQ parameters that will need to be part of a monitoring program aimed at measuring and assessing DS health and population dynamics under variable freshwater discharge conditions can be partitioned along physical-chemical and biotic lines. From a physical-chemical perspective, freshwater discharge (and related flushing and residence times), salinity, temperature, light transmission (determined by turbidity, water color and photopigments, most notably chlorophyll *a*), pH, dissolved oxygen, nutrient (total and dissolved inorganic N and P) and specific contaminant (Hg, Cd, Cu, etc.) concentrations should be measured. From a biological perspective, phytoplankton biomass (as chlorophyll *a*) and composition, zooplankton biomass and composition, benthic grazers (invertebrates), and key fish species densities and fecundity should be determined. If possible, benthic macrophyte density should be determined. Ecosystem-scale processes that would be important to measure include primary production, respiration and benthic oxygen consumption (especially in areas prone to hypoxia). Many of these parameters are likely included within the planned monitoring programs, but given the lack of specific information provided to the Panel, they are laid out here for completeness.

It is highly desirable to link the presence and densities of specific biological stressors to the Bay Delta system to DS densities and fecundity. Key stressors include harmful algal bloom taxa, namely toxin producing cyanobacterial species (*Microcystis* spp.), whose toxins are known to adversely affect resident invertebrate and fish species (including possibly DS). *Microcystis* blooms appear to be problematic from a food web perspective, because even though these blooms can produce large amounts of biomass, they are either avoided or not captured and assimilated by key crustacean (copepods, cladocerans) zooplankton species that serve as food source for DS and other ecologically- and recreationally-important fish species (Lehman et al. 2008). Invasive planktonic and benthic grazers have led to a "state change" in segments of the SF Bay where phytoplankton biomass exhibited a precipitous and sustained decline, following the establishment and proliferation of exotic bivalves (Alpine and Cloern 1992; Cole et al. 1992; Thompson et al. 1996; Jassby 2008). Lastly, the expansion of invasive aquatic macrophytes, e.g., Brazilian waterweed (*Egeria densa*) may also play a role in declining dominance of phytoplankton in some regions of the Delta. Ongoing monitoring data for these and other biological stressors should be incorporated into assessments of biotic factors potentially influencing health and population dynamics of the DS.

4.3 Fish

Abundance-based inferences concerning predator-prey interactions can be misleading, and high "signal-to-noise" ratios or low frequencies of occurrence can dramatically reduce the statistical power of abundance data. For these reasons, the panel suggests emphasis should be placed on developing a weight-of-evidence approach for organism condition and health. This recommendation is superimposed upon existing and proposed efforts to monitor organism abundance.

Effort should be made to maximize the amount of condition-related information that is obtained from collected DS. In addition to condition factor (CF, weight x $100/\text{length}^3$), measurable parameters include, but are not limited to, regression-based deviations from weight-at-length relationships (the use of archived specimens should be evaluated), direct estimates of fecundity, measurements of gonadosomatic and hepatosomatic indices, bulk lipid extraction or the possible use of C:N as a bulk lipid proxy (Post et al. 2007), lipid analysis (i.e., triacylglycerol to sterol ratio), and the creation of otolith-based growth-rate histories. Individual growth-rate histories can be matched to time series such as the outflow hydrograph and water temperature. These time-series comparisons will be limited by the short life span of the DS, but longer growth histories may be obtained from adult striped bass or by assembling individual series from archived DS otoliths, if these are available. Similar condition-oriented efforts should be directed toward important prey organisms using appropriate methods. For example, copepod egg production is commonly used as a growth or condition indicator.

4.4 Demographic Response

Owing to the low abundance of DS any positive response of population size to flow manipulation will be difficult to detect because any increases other than exceptionally high ones will be difficult to distinguish from sampling error. Other biological features of DS that are typically correlated with increased survival and population growth rates sizes, however, should be subject to less sampling error, owing to increased potential for replication, and thus be more sensitive to treatment effects. Three biological properties of DS that may be positively correlated with survival and population growth rates are individual growth rate and fecundity (which themselves should be positively correlated with each other in female DS) and CF. High individual growth rates are typically associated with increased survival of juvenile fishes as, for instance, larger fish of a given age are less susceptible to gape-limited predators (see review by Sogard 1997). Growth rates can be assessed for individual fish over daily periods by examining growth increments in otoliths (e.g., Sepúlveda 1994). In addition, fecundity is typically positively related to length in osmerids (Chigbu and Sibley 1994). The CF may be influenced by age, sex, season, stage of maturation, gut fullness, type of food consumed, amount of fat reserves, and the degree of muscular development. The CF¸ therefore, is usually positively associated with growth conditions experienced by, and performance of, individual fish. All of these features (growth rate, fecundity, CF), therefore, could be employed as proxy measures of positive demographic response of DS to Fall outflow treatment and should be added to the monitoring program.

<u>Recommendation 12</u>: The Panel strongly urges Reclamation and other agencies to formulate an explicit work plan for properly evaluating changes in the health and condition of DS in response to the X2 manipulation. The current document is woefully deficient on the details regarding the project's most important dependent variables. In the absence of reliable abundance data, how will health and condition of the DS population be evaluated? The Panel recommends that growth, condition, and fecundity be rigorously evaluated. **The revised draft must state how DS health and condition will be evaluated in regards to methodology, sampling design, and coordination of personnel.**

<u>Recommendation 13</u>: Parameters that measure the condition of predator and prey species should be targeted by 2011 monitoring and special studies, and those parameters that are found to be useful should be assimilated into long-term monitoring.

<u>Recommendation 14</u>: The Plan should incorporate monitoring of response variables in DS that have a clear demographic link to DS both at the individual and population level (e.g. otolith inferred growth rates, fecundity, condition factor).

__Recommendation 15__: **Reclamation must show how the proposed monitoring and assessment program will evaluate change from existing and ongoing monitoring programs.** Having a seamless before and after monitoring program for the proposed Action will facilitate understanding and quantifying the relationships between hydrologic forcing and biotic responses in the context of historic and future water discharge scenarios for the Delta.

5. Special Studies to improve understanding

The DoI technical guide on adaptive management (Williams et al., 2009) identifies '*assumption-driven research as central activities*'. In addition, Independent Science Advisors (2009) noted that research aimed at particular sources of uncertainty can be part of an adaptive management program. The panel has identified several areas where focused research or special studies can be used to reduce uncertainty surrounding the action and/or inform the implementation of future system manipulations.

5.1 Turbidity Studies

Researchers in the Delta have identified three primary mechanisms for generating turbidity, advection from the turbidity source through the Delta, wind resuspension, and from tidal flows. There is significant patchiness of turbidity with sharp fronts observed and lenses of higher turbidity water that are advected over large distances. Few details of the current Wright and Schoellhamer study were provided, but this study has the potential to investigate the relation between inorganic sediment, organic material and turbidity. Further, the study could also investigate the spatial heterogeneity of turbidity, the presence/absence of smelt with turbidity features and the spatial scale of these features. Data on DS, turbidity and salinity is primarily collected in main channels during routine monitoring. It would be useful to supplement these long term records with detailed observations of what is occurring in off-channel shallow areas. The ongoing sediment study and DS monitoring could be supplemented during this high flow year if these issues are not already being addressed. Applying some form of remote sensing to the problem of fine-scale patchiness may be productive, particularly in the more open waters of the Delta ecosystem.

5.2 Trophic Analyses

Although fish diet analyses are the most straightforward means of establishing the dominant linkages between fishes and their prey, observed diet compositions tend to reflect recent feeding in the general area of capture, and therefore can be easily biased by the distribution of the effort used to collect the fish. Fish should be collected at various tides and times of day to establish any consistencies in feeding times or tides. During implementation of the proposed AM Plan, particular care should be given to spatial and temporal changes in diet that occur as X2 shifts in response to outflow. Rare, sustained, high-outflow periods may result in changed prey assemblages. Spatiotemporal deviations in diet may also result from different prey assemblages being associated with different geographic sources of outflow (Sacramento River vs. San Joaquin River).

Once the diet of a given species has been adequately characterized for various stages and length classes, trophic levels can be calculated. Calculated trophic levels can then be corroborated using bulk stable isotopes. This process, which is extensively described elsewhere in the scientific literature (e.g., Vander Zanden and Vadeboncoeur 2002), yields a number of useful byproducts. One of these is the formal determination of the primary producers that constitute the trophic base – this is an essential component of the conceptual model that might otherwise remain unsupported by data. All types of primary producer should be evaluated in this process, including benthic microalgae and periphyton, which are often overlooked.

The trophic linkages identified by stable isotope analysis may be counterintuitive; many pelagic species have been demonstrated to have benthic linkages and demersal species have been shown to have pelagic linkages. As with diet data, trophic linkages vary over both space and time. For example, are centrarchids and other shoreline fishes more enriched in $d^{13}C$ than POD species? If so, this may be an indication of greater (indirect) dependence on periphyton, as suggested by Baxter et al. (2010, p. 103). Temporal shifts in trophic base between low and high outflow periods (or between high and low perimeter-to-area habitat ratios) can be formally tested using methods such as those presented by Schmidt et al. (2007).

Another useful byproduct is insight into the relative site fidelities of different species. Stable isotopes are rarely uniform across complex landscapes such as the Delta ecosystem. Fish that remain stationary will reflect local isotopic signatures, whereas those that move around or migrate systematically will integrate various aspects of the isotopic landscape, provided they continue to feed as they move. Attention must be paid to the types of tissues being analyzed, as these have different turnover rates and therefore represent different periods in the life of the fish.

5.3 Otolith microchemistry and Growth Ring Validation

A number of questions can be addressed using otolith chemistry. For example, do all DS have similar elemental profiles (core-to-margin laser-ablation transects), or do profiles from different individuals fall into groups according to their use of distinct habitats? Although DS may represent a single population in a genetic sense, there are different patterns of habitat use within the population.

Much of the utility of otolith microchemistry rests on the fact that elemental profiles reveal individual histories. Maturing DS in the estuary will retain elemental records of their earlier larval existences in fresh water, providing a natural tag for identifying individual origins. Do groups with different geographic origins have similar growth rates and potential contributions to recruitment, or do one or more geographic groups contribute disproportionately to the estuarine portion of the population? In addition, a laboratory study should be initiated using the captive population of DS to validate methods of daily growth ring analysis and the periodicity of formation. Validation of the daily growth ring deposition is critical for proper interpretation of growth rates of fishes inferred from otoliths.

5.4 Mesocosm studies

The experiment proposed in the draft AM Plan will be confounded by uncontrolled covariates of outflow, making detection of important processes difficult. As an alternative approach, controlled feeding experiments using captive organisms can be applied within aquaria or mesocosms, isolating and quantifying effects on the DS in its role as predator and as prey. A two-way factorial design including turbidity and water temperature may be appropriate.

Suggested special studies include additional diet analyses, stable-isotope-based analyses of trophic dependences, identification of individual fish habitat histories using otolith microchemistry, and mesocosm experiments for defining the controlled effects of temperature and turbidity on DS feeding and vulnerability to predation.

5.5 Linkages between Physical Habitat and Forage Food

The conceptual model that motivates this large experimental manipulation is partially reliant on the assertion that expansion of DS physical habitat also increases habitat quality due to increases in forage food. Native and non-native zooplankton abundances are known to be enhanced in the western portion of the Delta during the fall. These zooplankton populations likely contribute to the predicted enhancement of the "health and condition" of DS in this zone. The overall scientific success of the project would greatly benefit from an evaluation of zooplankton abundances, growth rates, and fecundity in the experimentally-manipulated zone of the Delta. The draft AM Plan had scant detail on planned zooplankton monitoring and evaluation, but additional materials provided by Dr. Anke Mueller-Solger document: 1) the extent of peer-reviewed publications on the foraging ecology of DS, 2) the existing capabilities of the delta science community for expertly characterizing delta zooplankton populations and ecological attributes (including growth, food quality, and fecundity), and 3) translation of zooplankton community ecology into a thoughtful conceptual model of the DS life-cycle and population dynamics. The Panel is highly supportive of special studies that examine zooplankton community ecology during and after the X2 experimental manipulation.

6. Organization, Logistics and Flow of Information

The Panel is extremely concerned about the limited amount of time between our review and implementation of one of the largest freshwater ecosystem-level manipulations ever conducted. The Panel has serious reservations about the successful implementation of this ambitious venture due to concerns regarding: 1) explicit clarity of the hydrologic manipulation of the system to achieve the X2 criteria, and 2) explicit clarity of the key independent and dependent variables that will be evaluated to document success of the experimental manipulation (discussed above).

The Panel is also concerned about whether the participating agencies of this ambitious plan are equipped to execute the plan at the level of commitment and performance that will satisfy: 1) the inherent costs of the X2 manipulation endeavor, 2) general public and scientific public buy-in on potential fish recovery, knowledge discovery and gains in public education. The Panel is concerned that a failure to effectively describe the experiment and document response will “haunt and handicap” individuals and agencies involved in the effort for years to come.

The Panel is impressed by the commitment of scientists and agency leaders to the Delta ecosystem in regards to efficient, strategic water conveyance and effective ecosystem management. The over-arching comments are simply geared to gaining the best and most useful data from a potentially once in a decade manipulation, that has little precedence in the freshwater or estuarine ecological literature. Panel comments are also geared to help focus all agencies involved on the incumbent task at hand. Reclamation and the Service will be saturated with commitments this summer and fall, but it is recommended that senior leadership in all agencies consider the following pragmatic recommendations from our panel:

- There needs to be extensive institutional commitment to the project in all ranks of organization, and the leaders of Reclamation, the Service, DWR, USGS, and others MUST view the experiment as high priority for the next year. Other projects and tasks will have to become secondary. The professional reputations of agency scientists, managers, and leaders are greatly affected by the execution, success, translation, and professional correspondence of this potentially once-in-a-lifetime experiment.

- The Panel urges agency leaders to provide their top-scientists and managers with all of the resources to not just implement, or even loosely exceed, the execution of the experiment, but to excel in the scientific discovery that allows substantial gains to both Delta science and societal awareness of the challenges and potential gains of ecosystem manipulations.

- Walters (2007) provided a summary of common issues that can compromise the successful planning, implementation, and veracity of conclusions derived from adaptive management in fisheries. One key characteristic of adaptive management initiatives that did not meet expectations was a lack of commitment by all participating agencies to provide a single individual <u>who is given the freedom to commit all the necessary time and energy to making sure the manipulation is implemented as his/her top priority.</u> It is, therefore, essential that the Fall outflow plan be under the overall direction of a single individual and that this individual be given the freedom and authority to ensure that the planning, implementation, and evaluation/ monitoring of the subsequent effects be her/his top priority.

Recommendation 16: **The Fall outflow plan leadership team should include one individual who is given the freedom to ensure that the implementation and monitoring of the plan is her/his top priority and principal responsibility for the next year starting July 1, 2011.** The Panel urges leadership at Reclamation and other invested agencies to be responsive to requests for resources, especially time commitments from the agencies most qualified scientists and managers.

7. Relevant Lessons from other Ecosystem Management programs

Implementation of adaptive management in other large ecosystems has helped set precedents and lessons from these programs may assist managers implementing adaptive strategies for Fall outflow.

7.1 Colorado River Ecosystem Downstream from Glen Canyon Dam

Ecosystem-level manipulations of freshwater ecosystems are unusual at spatial scales larger than headwater streams and small lakes, thus the proposed experimental manipulation of the fall freshwater zone of the Delta is noteworthy. While there are a growing number of adaptive management studies that can be used for context and insight when describing the importance of this Fall outflow, there are few explicit manipulations at this spatial-scale. One potential analog is the experimental flooding of the Colorado River using releases of Glen Canyon Dam water. The experimental water manipulations were relative short in duration (weeks) and involved three experimental releases. The experiments were motivated by the assertion that homogenized river flow had altered the river's geomorphology in a manner that was detrimental to native fish such as the threatened humpback chub population (endemic only to the Colorado River downstream of Glen Canyon Dam) and possibly beneficial to exotic fish species that are humpback chub predators. Improvement of the humpback chub's abiotic, physical habitat was predicted to improve spawning habitat and predator avoidance. Multiple state and federal agencies were involved in the project that required multiple years to prepare and assess. This was a high-profile experiment that required effective public relations throughout the general public, NGOs, agencies, and scientists. Refer to report: http://pubs.usgs.gov/of/2010/1128

7.2 Chesapeake Bay, Albemarle-Pamlico Sound and the Role of Emerging Technologies and Models

Chesapeake Bay and North Carolina's Albemarle-Pamlico Sound system are the US's largest estuarine ecosystem, and like many other estuaries, reveal a great deal of heterogeneity in the amounts and distributions of phytoplankton and suspended sediments. These entities are notoriously difficult to spatially assess and quantify in these hydrologically and biogeochemically dynamic estuaries. Aircraft-based remote sensing, including aircraft-based SeaWiFS, and Lidar have been effective in quantifying these optically-active constituents of the water column. Examples of the application of aircraft-based SeaWiFS in quantifying seasonal distributions of Chl *a* are provided for both systems (Figures 7.1 and 7.2). These technologies are applicable to the Bay Delta and estuary (see Harding and Miller 2009).

The use of technology to identify synoptic patterns in water quality parameters is one lesson from Chesapeake Bay and Albemarle-Pamlico Sound. While there are likely many more, another of relevance to this study is the use of models to assess change in the system in response to management actions. In October 2005 the Government Accounting Office (GAO, 2005) assessed reports used by the Chesapeake Bay program to identify progress toward their goals and noted 'Moreover, the credibility of these reports has been negatively impacted because the program has commingled various kinds of data such as monitoring data, results of program actions, and the results of its predictive model without clearly distinguishing among them'. The reliance of Reclamation on a model and surrogate measures, e.g., fall habitat suitability index to assess the quality of the outcomes of the action to DS should be reconsidered. Overreliance of models to predict outcomes based on cause-effect relationships within a model rather than through field data for Chesapeake Bay was seen as problematic by many. This re-emphasizes the need for Reclamation to focus on measuring growth and condition on DS as the outcome of the intended action.

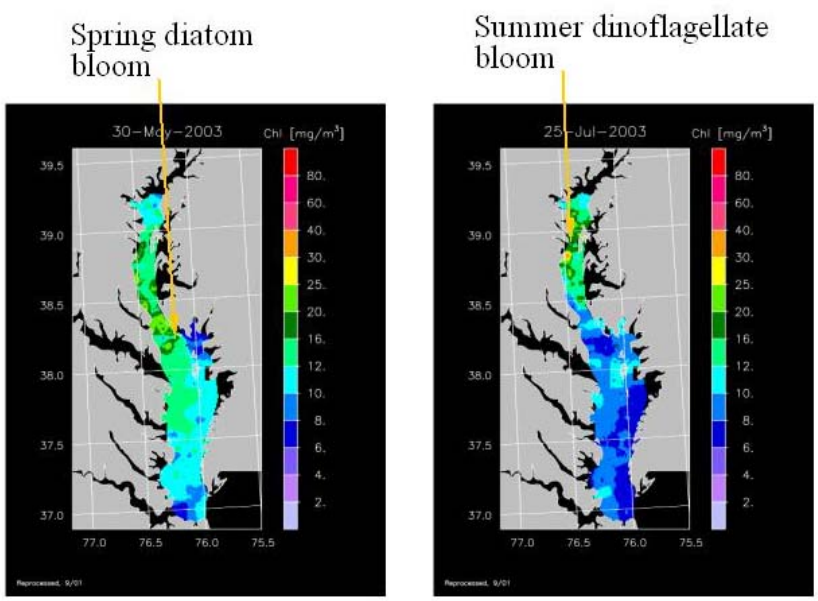

Figure 7.1: Contrasting spring and summer Chl-*a* distributions in the Chesapeake Bay, during May and July 2003. Surface water Chl *a* concentrations were estimated using aircraft-based SeaWiFS remote sensing (Courtesy L. Harding, Univ. of Maryland), calibrated by field-based Chl *a* data. In May,

when flow is high, a large diatom bloom extends into the lower Bay. During lower flow July a dinoflagellate bloom was observed in the upper Bay (From Harding and Miller, 2009).

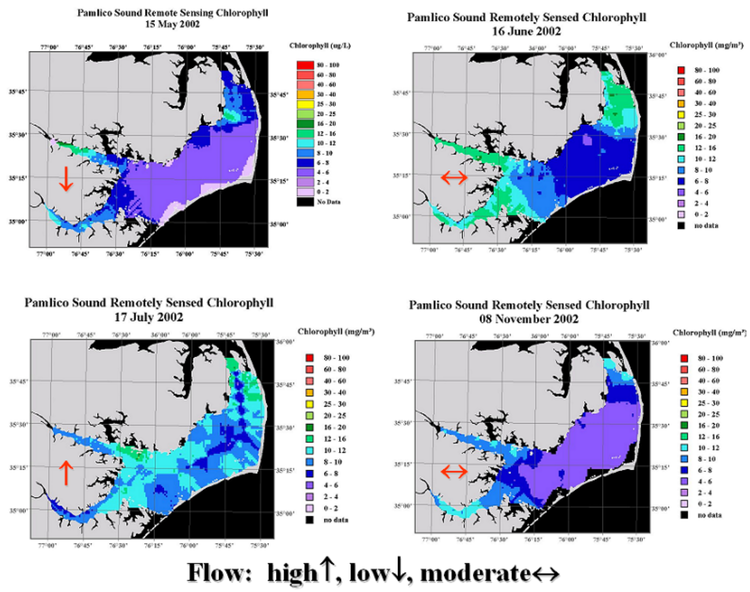

Figure 7.2: Spatial relationships of phytoplankton biomass, as chlorophyll *a* (Chl *a*), and freshwater discharge to the Pamlico Sound System, NC. Surface water Chl *a* concentrations were estimated using aircraft-based SeaWiFS remote sensing (Courtesy L. Harding, Univ. of Maryland), calibrated by field-based Chl *a* data. Under relatively low-flow, long-residence time conditions, phytoplankton biomass is concentrated in the upper reaches of the Neuse and Pamlico R. Estuaries. Under moderate flow, phytoplankton biomass maxima extend further downstream. Under high flow (short residence time) phytoplankton biomass maxima are shifted further downstream into Pamlico Sound (figure adapted from Paerl et al. 2007).

7.3 Neuse River Estuary

Mechanistic models, based on long-term monitoring efforts have however been quite useful once the hydrodynamic “behavior” of an estuary, including its response to acute and chronic changes in freshwater input have been well characterized. One example is the nutrient-water quality response model that is in place in the Neuse River Estuary, the largest tributary of North Carolina’s Albemarle-Pamlico Estuarine complex. This response model, a modification of the CE-Qual model (Bowen and Hieronymous 2003), has been effective in predicting, among other parameters, chlorophyll *a* exceedances of the North Carolina standard of 40 μg per liter for Total Maximum Daily (Nitrogen) Load Development aimed at controlling eutrophication and harmful algal blooms in this nitrogen-sensitive estuary (North Carolina Department of Environmental and Natural Resources, 2009). The successful application of this model for evaluating the TMDL is largely attributable to a long-term spatial-temporal intensive water quality monitoring program that has been in place since 1994 (Paerl et al., 2007). Further details of ModMon - http://www.unc.edu/ims/neuse/modmon/index.htm

7.4 Florida Everglades Restoration Program

Of all similar large-scale ecosystem management programs, perhaps the Everglades has the most resemblance to the challenges of the Sacramento Delta. The Senate Committee on Environment and Public Works in July 27, 2000 stated:

> *"The Committee does not expect rigid adherence to the Plan as it was submitted to Congress. This result would be inconsistent with the adaptive assessment principles in the Plan…Instead the Committee expects that the agencies….will seek continuous improvements of the Plan based on new information, improved modeling, new technology and changed circumstances."*

In a recent retrospective on the lessons learned on the incremental adaptive restoration strategy used in the Everglades, Dr. Ronnie Best, Coordinator of the Greater Everglades Ecosystem Science program stated that every program must have a champion and a dedicated coordinator of AM (Personal Communication, 2011). He also stressed that AM should be 'done BIG and LEARN'. Learning included science, modeling, financing, and permitting.

Further details are available in the Science Plan in Support of Ecosystem Restoration, Preservation and Protection in South Florida (DOI, 2006) [www.sofia.usgs.gov] and Facing Tomorrow's Challenges, USGS Science in the decade 2007-2017. USGS Circular 1309.

7.5 Other Florida Estuaries

Fish condition can be measured as deviations from weight-at-length relationships (Figure 7.3). In the Alafia River estuary of west-central Florida, these deviations clearly document distinct annual cycles in fish condition that are strongly correlated with freshwater inflow. In Figure 7.3, the negative relationship between inflow and condition reflects interaction between fish center of abundance (analogous to X2) and a downstream estuarine area that is highly prone to hypoxia during the summer rainy season. Note that the strength of this effect varied extensively among the eight years examined. Obtaining fish weights and lengths was automated using RS232 output from electronic calipers and balances, with the instrument output being organized by direct-data-entry software.

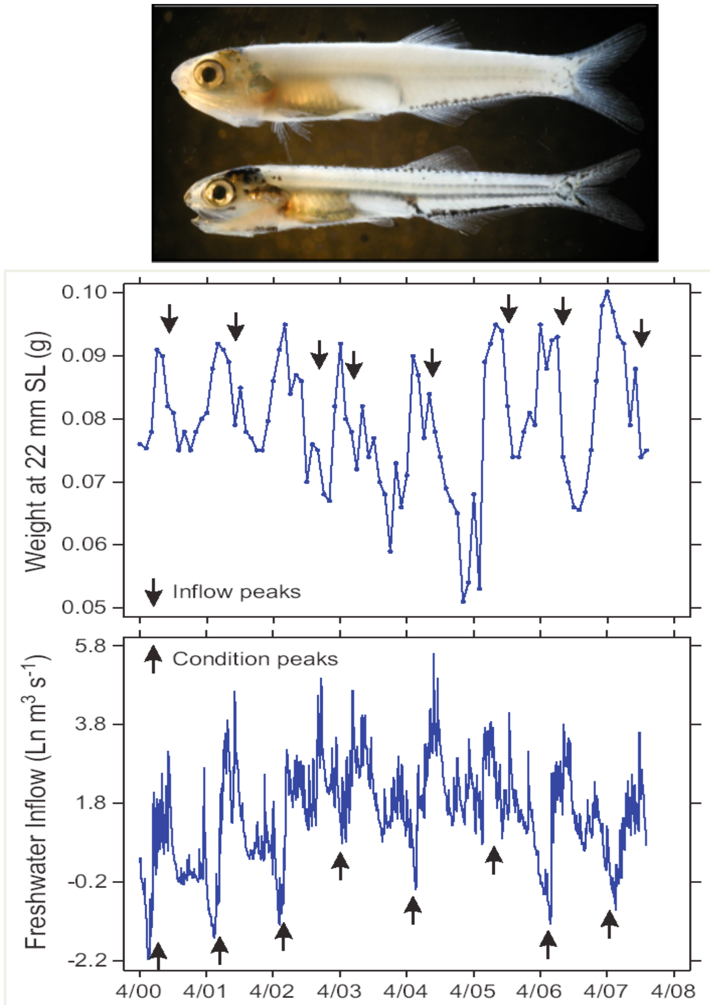

Figure 7.3: Example of fish condition co-variation with freshwater inflow (Alafia River estuary, west-central Florida). Variation in the condition of bay anchovy (*Anchoa mitchilli*) juveniles is apparent even without formal measurements (photo at top). Juveniles were collected during monthly sampling from April 2000 through November 2007, and monthly weight-length regressions were then created retrospectively using preserved specimens (a reference length of 22 mm was selected to avoid extrapolation of predicted means). Many estuarine taxa, including bay anchovy juveniles, move upstream and downstream as freshwater inflows vary (Flannery et al. 2002). High inflows during the summer rainy season (lower plot) cause the juvenile bay anchovies to be positioned downstream over a dredged ship channel at the mouth of the estuary. The ship channel is invariably density-stratified and hypoxic during summer. The fish become emaciated (upper plot) when their center of abundance is positioned over the hypoxic ship channel each summer (Peebles et al., MS in prep.).

<u>Recommendation 17:</u> When finalizing the plan, the authors should incorporate lessons from other large-scale ecosystem restoration or AM plans, especially those in other litigious environments such as the Everglades, Chesapeake Bay and the Colorado River. The biennial National Conference on Ecosystem Restoration (NCER) provides an opportunity for managers and scientists to share experiences of large-scale adaptive management (http://conference.ifas.ufl.edu/NCER2011/).

8. Summary Conclusions

The Draft Adaptive Management Plan for Delta Fall outflow provides a preliminary roadmap for the approach that Reclamation intends to adopt to address the RPA in the 2008 Biological Opinion. The BiOp was based on the best available knowledge at the time, but the 2011 high flow year offers an opportunity to demonstrate the effectiveness of the proposed action in the RPA. The Panel appreciates the opportunity for early review and found no fatal errors in the scientific approach, but critical details were not included in the plan description. In general, the manipulation planned appears feasible in terms of conceptual grounding and the fact that the response monitoring proposed will employ well-established techniques in water quality determination, habitat assessment, and fish biology. Much more detail, however, is required concerning the mechanics of flow manipulation (see **section 2.2**) in order to determine the feasibility of *how* flow is to be manipulated. In addition, the planned action and monitoring will only be feasible overall if the required coordination amongst agencies is complete, and the commitment to the appropriate and singular leadership outlined in **section 6** is provided.

The following summary conclusions are recommendations intended to assist Reclamation and the Service in planning the next few weeks leading up to the X2 releases or curtailed pumping.

I. Be bold and create an opportunity where the direct benefits to DS and challenges for water deliveries can be clearly quantified. This increased understanding will help the entire Delta Community stake-holders to plan and manage better in future years.

II. Focus on the Action and monitoring for 2011, making sure to functionally connect before,during, and after release event monitoring data and assessments. The fine details of AM in out years can be developed in the coming months. The final AM Fall outflow plan should also embrace an ecosystem approach that acknowledges that the Action will impact multiple species and biogeochemical processes due to the finite availability of cold water in any year.

III. Clearly define the Action. Obviously the objective is to achieve the X2 standard at the minimum cost to water deliveries. Will a steady state high flow be used or pulsing of flows during September and October, and will this be conducted in conjunction with curtailed pumping?

IV. Design the action and monitoring based on the results of models such as UNTRIM. The objective is to get desirable salinities and turbidities to coincide over large areas of potential habitat, and then see if DS utilize the habitat and understand the change in DS size and decrease in mortality. Simulation of the selected Action can then be used to design the monitoring program. The simulations should also make clear how the releases will be routed from the upstream reservoirs to the upstream boundaries of UNTRIM.

V. Monitoring of salinities, turbidity and DS location during the manipulation can be used to assess the accuracy of the UNTRIM model for particle tracking, salinity (and turbidity if SEDIMORPH algorithms are linked to UNTRIM). If the predictive capability of UNTRIM is proven to be reliable, the Action could be modified in real-time to maximize the amount of 'suitable' DS habitat.

VI. If the predictive capability of UNTRIM is proven to be reliable, the Action can be modified in real-time to ensure the X2 standard is achieved.

VII. The AM Plan should clearly define which data are being used for different monitoring objectives, including:

- annual baseline monitoring to provide trend and change information
- compliance monitoring to ensure that the X2 standard is achieved
- model refinement that will improve the confidence in the UNTRIM model results for future management decisions
- refinement of the DS conceptual model and Newman et al. DS life cycle model
- evaluation of the effectiveness of the RPA in sustaining the DS population
- quantification of the conventional wisdom regarding linkages between physical habitat criteria and the recovery of the DS population
- fundamental science questions that will resolve larger and more general questions about the Delta ecosystem (refer to the draft AM Plan and Section 5 of this report)

VIII. Consideration should be given to appointing an AM Coordinator and a logistics manager to conduct the monitoring programs and be responsible for the scientific outcomes.

IX. The study and monitoring plan should be made public, with an open invitation for complementary studies that could be conducted in tandem with the Fall outflow monitoring and special studies. This could create a quantum leap in the understanding of the functioning of the Delta system.

The 2011 Wet Year provides an opportunity for a quantum leap in our fundamental understanding of delta processes and help resolve some of the basic questions posed by the BiOp. If designed properly, the Fall 2011 Outflow release will allow stake-holders to develop a common knowledge of delta functions that will have profound implications to the future management of the Delta.

References

Alpine, A.E., and Cloern, J.E., 1992, Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary: *Limnology and Oceanography* 37: 946-955.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. Interagency Ecological Program Pelagic Organism Decline Work Plan and Synthesis of Results.

Bowen, J. D., and J. W. Hieronymus. 2003. A CE-QUAL-W2 Model of Neuse Estuary for Total Maximum Daily Load Development. *J. of Water Resources Planning and Management*. 129(4): 283-294

Chigbu, P., and T.H. Sibley. 1994. Relationship between abundance, growth, egg size and fecundity in a landlocked population of longfin smelt, *Spirinchus thaleichthys.* Journal of Fish Biology 45: 1-15.

Cole, B.E., J.K. Thompson and J.E. Cloern. 1992. Measurement of filtration rates by infaunal bivalves in a recirculating flume. *Journal of Marine Research* 113:219-225.

Flannery, M.S., E.B. Peebles and R.T. Montgomery. 2002. A percent-of-flow approach for managing reductions of freshwater inflows from unimpounded rivers to southwest Florida estuaries. *Estuaries* 25: 1318–1332.

Government Accounting Office. 2005. Improved Strategies Are Needed to Better Assess, Report, and Manage Restoration Progress. GAO-06-96

Harding, L. W. and W. D. Miller. 2009. Airborne remote sensing of chlorophyll in Chesapeake Bay, USA. *in* X. Yang, editor. *Remote Sensing and Geospatial Technologies for Coastal Ecosystem Assessment and Management*. Springer, New York. 115-138.

Independent Science Advisors. 2009. Bay Delta Conservation Plan Independent Science Advisors' Report on Management, prepared for the BDCP Steering Committee, February 2009. Available at: *http://baydeltaconservationplan.com/Libraries/Background_Documents/BDCP_Adaptive_ManaGement_ISA_report_Final.sflb.ash.* Last accessed on April 11, 2011.

Jassby, A. 2008. Phytoplankton in the Upper San Francisco Bay Estuary: Recent biomass trends, their causes and their trophic significance. *San Francisco Estuary and Watershed Science* February 2008:1-24.

Kimmerer W.J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science [online serial]. Vol. 2, Issue 1 (February 2004), Article 1. http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Lehman, P.W., G. Boyer, M. Satchwell and S. Waller. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. *Hydrobiologia* 600:187-204.

North Carolina Department of Environmental and Natural Resources. 2009. Neuse River Basinwide Water Quality Plan-2009. NC DENR-DWQ, Planning Section, N. Deamer. July 2009. Raleigh, NC.

Nunes, S., 2011. The Role of Information Technology in Sustaining the World's Water Systems. *Plenary Lecture, IAHR World Congress*, Brisbane. www.iahr.net

Paerl, H.W., L.M. Valdes, A.R. Joyner, and V. Winkelmann. 2007. Phytoplankton Indicators of Ecological Change in the Nutrient and Climatically-Impacted Neuse River-Pamlico Sound System, North Carolina. *Ecological Applications* 17 (5): 88-101.

Post, D. M., C. A. Layman, D. A. Arrington, G. Takimoto, J. Quattrochi, C. G. Montaña. 2007. Getting to the fat of the matter: models, methods and assumptions for dealing with lipids in stable isotope analyses. *Oecologia* 152:179–189.

Rooney, N., K. McCann, G. Gellner and J. C. Moore. 2006. Structural asymmetry and the stability of diverse food webs. *Nature* 442: 265-269.

Schmidt, S. N., J. D. Olden, C. T. Solomon, and M. J. Vander Zanden. 2007. Quantitative approaches to the analysis of stable isotope food web data. *Ecology* 88: 2793–2802.

Schoellhamer, D.H., 2011. Sudden clearing of estuarine waters upon crossing the threshold from Transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bat, 1999. *Estuaries and Coasts.* DOI 10.1007/s12237-011-9382-x

Sepúlveda, P. 1994. Daily growth increments in the otoliths of European smelt, *Osmerus eperlanus. Mar. Ecol. Prog. Ser*. 108: 33-42.

Sogard, S.M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: a review. *Bull. Mar. Sci*. 60: 1129-1157.

Thompson, J.K. and F.H. Nichols. 1996. Control of a phytoplankton bloom in San Francisco Bay, California by the filter feeding bivalve *Potamocorbula amurensis* [abstract]. *Proceedings of the Pacific Division of the American Association for the Advancement of Science* 13:98.

Vander Zanden, M. J. and Y. Vadeboncoeur. 2002. Fishes as integrators of benthic and pelagic food webs in lakes. *Ecology* 83: 2152–2161.

Walters, C.J. 2007. Is adaptive management helping to solve fisheries problems. *Ambio* 36: 304-307.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Appendix I: The Scientific Review Panel Charge

DELTA SCIENCE PROGRAM
INDEPENDENT SCIENCE REVIEW

Adaptive Management Plan for Delta Fall outflow

PLAN GOALS AND ADAPTIVE MANAGEMENT

The goals of the plan are (1) to manage Fall outflow for conservation benefits to delta smelt while minimizing water supply and water supply reliability impacts; (2) to increase understanding about the effectiveness of Fall outflow for smelt conservation in order to adjust the action for better conservation effect or water efficiency.

REVIEW PANEL CHARGE

The Review Panel will be charged with assessing the Plan for Adaptive Management of Delta Fall outflow from several points of view, with emphasis on the use of the Plan as an adaptive management tool. Specific attention will be applied to the following criteria:

Purpose

- Is the plan responsive to recommendations in the 2008 US Fish and Wildlife Service Biological Opinion on the Central Valley Project and the State Water Project?
- Are the goals of the plan consistent with the goals of the Reasonable and Prudent Alternative?
- How well will the plan, as designed, meet its two major goals: (1) to manage Fall outflow for conservation benefits to delta smelt while minimizing water supply and water supply reliability impacts; (2) to increase understanding about the effectiveness of Fall outflow for smelt conservation in order to adjust the action for better effect and/or water efficiency?
- Is the plan clearly defined and described?
- Is the plan internally consistent and scientifically valid?
- Is it clear for what purpose and how the plan might be used?
- Will implementation of the plan adequately provide the information necessary for refining the goals and objectives, knowledge base and models, and approach of the plan over time?

Approach

- Are linkages between elements of the plan clear?
- Is the use of hypotheses, conceptual models and quantitative models clear and helpful? If not, how might this be changed or refined?
- Will the monitoring and evaluation program result in adequate detection of signal to noise (inherent variability)?
- Is the decision matrix for adaptive management clear and useful?
- Does the plan contain adequate provision for synthesis, evaluation, and reporting?
- What, if any, future role/need is there for additional scientific input and review?

Feasibility

- Is the approach described in the plan feasible to implement?
- If not, what can be done to improve feasibility of the approach?

The following background materials were provided to the Review Panel:

✓Final 2010 POD Report (http://www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf

✓Coordinated Operations Biological Opinion (USFWS 2008) RPA Component 3 and associated explanatory material in the RPA and BiOp (http://www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf)

✓Independent Review of Two Sets of Proposed Actions for the Operations Criteria and Plan's Biological Opinion (PBS&J, 2008) (http://www.fws.gov/sacramento/es/documents/Peer%20review%20of%20proposed%20actions%2011-19-08.pdf)

✓NRC March 2010 panel report

(http://www.nap.edu/catalog.php?record_id=12881

✓DOI Technical Guide

(http://www.doi.gov/initiatives/AdaptiveManagement/)